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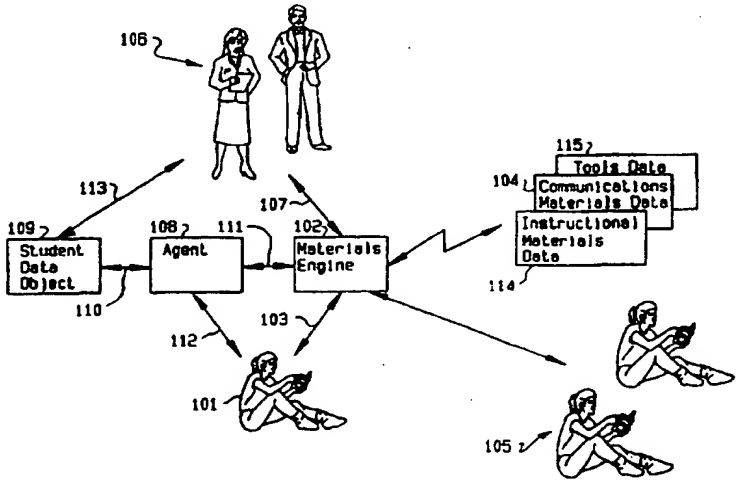

(57) Abstract

This invention relates to a system and method for interactive, adaptive and individualized computer assisted instruction. This invention includes an agent (108) for each student (101) which adapts to its student, and provides individualized guidance to the student and controls to the augmented computer assisted instructional materials. The instructional materials of this invention are augmented to communicate the student's performance and the material's pedagogical characteristics to the agent, and to receive control from the agent. Preferably, the content of the communication between the agent and the materials conforms to specified interface standards so that the agent acts independently of the content of the particular materials. Also preferably, the agent can project using various I/O modalities integrated, engaging, life-like display persona(e) appropriate to the preferences of its student, and appear as a virtual tutor to the student. Finally, preferably this invention is implemented on computers interconnected by a network.

constrained domains, such as a single school system or corporate enterprise.

Existing CAI systems have not addressed these functional deficiencies nor have they exploited the possibilities of existing technologies.

Citation of references hereinabove shall not be construed as an admission that such a reference is prior art to the present invention.

3. SUMMARY OF THE INVENTION

The Agent Based Instruction ("ABI") system of this invention is a system and method for interactive, adaptive, and individualized computer-assisted instruction and homework, preferably implemented on network connected computers, that overcomes these problems by providing the following objects in preferred and alternative embodiments. This invention provides a more effective system responsive to the needs of several parties interested in education.

An important object of this invention is to provide the student with a virtual tutor, by having agent software ("agent") adapted to each student that offers a high quality of individualized student interaction and that manages or controls instruction in a manner approximating a real tutor. The agent exercises management or control over the computer-assisted instruction materials and provides information and help to the student, both synchronously and asynchronously to particular instructional materials. Agent behaviors are sensitive to both the educational context and to the history of student behavior.

In a preferred embodiment of this invention the agent integrates data from several sources. From computer-assisted instructional materials, it accepts data on the methods of instruction adopted by particular materials and on student performance in the instruction. From the student, it accepts direct interactions as well as using the history of previous student performance stored in a student data object. From the teacher, it accepts data on customization and student

Important teacher activities are included in the following list.

1. The teacher initializes and exercises continuing control over important data in the student data object, and in this manner supervises the student's use of the system. For example, the teacher controls the access and level of tools available to the student and limits the extent to which the student can alter agent personae.

2. The teacher controls the student's use of the ABI system by assigning, scheduling, and prioritizing the student's access to the materials. This is accomplished by teacher control over the schedule subtype in the student model object. For example, the teacher can schedule tasks that must be completed on the ABI system, schedule non-system tasks, remove tasks or modify their priorities.

3. The teacher can customize materials available to the students. The extent of routine customization includes modifying sequencing of instructional lessons, elements, and items, choosing the homeworks the student must complete, specifying the formats of homework assignments having some student discretion, such as reports, sending messages to students.

4. The teacher's class management is aided by a facility to send messages, reminders, hints, etc. to students using the ABI system e-mail facilities.

The system can advantageously assist the teacher in homework management. Once the student completes and submits a homework assignment, a printed copy can be made for the teacher and the student. The homework assignment can be graded by the ABI system, if answers were provided as part of homework material. The teacher can add comments for the student, if homework is viewed online by teacher.

The system can advantageously also provide the teacher with summary and detail reports for each student and class. These reports can be immediately available online or printed for later review. As known in the art, reports can contain both current and cumulative data on instructional progress

5.5.2.3. **The Scheduler/Calendar Tool**

The schedule/calendar is an important tool and is preferably always present. It is accessed when the ABI system initiates materials to verify the student is permitted and scheduled for this material, and also invoked when the system terminates materials to schedule new materials. It is accessed as a global function by the agent in response to a meta-request from the student seeking scheduling assistance. Further, it can be directly accessed by the student using the calendar tool icon appearing on the student desktop. When accessed, this tool displays a calendar book to the student, viewable in several ways.

This section describes, first, the schedule/calendar data, and second, the schedule/calendar processing. The schedule/calendar data is a subtype of and contained in the student data object. Generally, this data includes the following fields for each scheduled student activity:

Name of scheduled activity and optionally an identifying message;

Activity priority;

Deadline date and time, or a definition of a perpetual activity, which has periodic requirements but no completion date;

Link to material for the activity which in turn can specify activity completion criteria; for activity of a single student this is typically a particular instructional material; for group work activity a list of the students for the group and other communication information can also be in the calendar entry;

Activity characteristics, for example whether this was entered by the student or teacher and whether this is to be marked complete by the student or system;

Activity status, completion status and submission status of any required reports.

This exemplary data, sufficient to define a scheduled activity, can alternatively be entered by the teacher or by

as contests with rules. Each of these forms of group work or communication is described in the remainder of this section.

A first form of group work implemented by communication materials is E-mail and newsgroups. These are useful for teachers to send information to their classes, such as schedule and materials changes and to communicate with absent students. Teachers can also exchange information with each other or obtain help for system and other issues. Students can use this form to obtain help and advice, especially from remote sources, communicate with their teachers, and share work or interests with other students. E-mail and newsgroups are easily incorporated as previously discussed. Then materials data is authored that grants access to these functions and generates appropriate agent event messages.

Student linking is another form of group work implemented by communication materials. Students in session at separate clients can link together for various exemplary activities including simply talking with each other by voice or text or for joint work on a particular material in which the students have either similar roles, as in developing a document using a word processor, or different roles, as in a simulation or game. Another activity of linked students includes group activities, in which position of participants within a virtual environment determines activity and role within activity. A final exemplary activity for linking student groups is moderated activity, in which participation is controlled by a special coordinating task that perhaps executes on a server system. An example of this latter activity is a spelling bee which is described in more detail subsequently.

In the preferred embodiment, student linking includes the following steps. The first step is identification of other students with whom a given student can link. The group can be defined by the teacher in the schedule/calendar entry for this activity, or alternatively, in a communication access control particular to this linked work activity. Second, links must be established between the students to be

5.6.1. Student Data Object

One student data object is created for each student in the ABI system and is the only permanent repository of data concerning that student. The student data comprises fixed data defining the student as well as evolving data describing the student's interaction with the system, the latter including current and past performance and data defining the agent's view of the student. The student data object is stored on the server system and is the source on the server system for all teacher and administrative reports concerning that student. Elements of the student data object are fetched to a client system as required once its associated student logs on to that client and on that client serves to control the agent and provide for agent adaptivity.

Figs. 10A, 10B and 11 illustrate the structure and operation of the student data object. Figs. 10A and 10B conceptually illustrates an exemplary structure for student data object 1101. It is an object comprising structured student data 1102 and methods 1103 for accessing and updating the student data. Student data is divided into global data 1104, materials related data 1105, including tool related data 1106, current lesson data 1107, and log data 1108. Global data, that is all items meaningful across all ABI materials, includes such subtypes as system data, agent behavior preference data 1109, agent student model data 1110, and schedule data 1111. System data includes student identifiers, student passwords, access privileges, grade levels, class registrations, etc. Agent behavior preference data 1109 relates to the multi-modal behaviors generated by the agent and includes student defined preferences for these behaviors as well as a summary of past agent behaviors. Student preferences can include options relating to agent visual appearance - species, gender, dress, or perhaps, no visual appearance - and similar options relating to audio behavior and text production. The summary of past agent behaviors is used to aid in the selection of reasonably varied future multi-modal behaviors. Agent student model

In another alternative embodiment, the student data object has data modeling student interests and preferences. Such a model enables the agent, for example, to monitor school events and suggest those appropriate to the user. This model also enables the agent to provide rewards tailored to individual students, which enhances the system reinforcement and adds to perceived agent persona personality and to virtual tutor individualization. In a preferred embodiment, this model of student interests can be implemented simply as a set of approximately 200 categories, covering interest in several subdivisions of each school subject area, as well as categories related to sports, leisure time and other areas of student interest. Interest in these categories can be entered in several manners. Student use of the encyclopedia tool can be used to determine areas of current interest. Interest can be directly entered by the student, parent, or teacher. Alternately, student interest in materials can inquired for when the materials terminate. After an assignment, the student could provide semiotic feedback by selecting from a row of faces with different expressions. Alternately, the student can be quizzed on interests in a posed branching manner.

6. SPECIFIC EMBODIMENTS, CITATION OF REFERENCES

The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

Various publications are cited herein, the disclosures of which are incorporated by reference in their entireties.

WHAT IS CLAIMED IS:

1. A method of operating an agent based instruction system for interactive instruction of a student over a plurality of instructional sessions, said method comprising:

(a) presenting interactive instruction to said student by executing one or more materials on a computer accessed by said student for a current instructional session;

(b) monitoring said interactive instruction of said student during said current instructional session;

(c) storing information responsive to said monitoring of said student during said current instructional session for use during subsequent instructional sessions; and

(d) outputting information on said computer to guide said student in said interactive instruction, said output information responsive to said monitoring of said student during said current instructional session and to said stored information responsive to said monitoring of said student during previous instructional sessions;

whereby said system acts as a virtual tutor adapted to said student, said virtual tutor for guiding said interactive instruction of said student.

2. The method according to claim 1 further comprising after said step of monitoring a further step of controlling said one or more materials, said controlling responsive to said monitoring of said student during said current instructional session and to said stored information responsive to said monitoring of said student during previous instructional sessions, and wherein said one or more instructional materials are responsive to said controlling;

whereby said interactive instruction presented by said system is individualized to said student.

3. The method according to claim 2 wherein said step of monitoring further comprises monitoring pedagogic

characteristics of said interactive instruction of said student by said one or more materials, and said step of controlling further comprises controlling said one or more materials in order to present interactive instruction with said pedagogic characteristics.

4. The method according to claim 3 wherein said pedagogic characteristics are selected from the group comprising time pacing of interactive instruction, new concept seeding rate, density of examples, and discrimination difficulty.

5. The method according to claim 2 wherein said step of monitoring further comprises monitoring according to an instructional context and an instructional format adopted by each of said one or more materials.

6. The method according to claim 2 further comprising before said step of controlling and said step of outputting a further step of generating at least one action responsive to said monitoring of said student during said current instructional session and to said stored information responsive to said monitoring of said student during previous instructional sessions, and wherein said step of controlling is responsive to said generated action(s) and wherein said step of outputting is responsive to said generated action(s).

7. The method according to claim 6 wherein said of generating step generates action(s) according to one or more tables of rules.

8. The method according to claim 6 wherein said of generating step generates action(s) according to one or more methods selected from the group of expert systems, neural networks, Bayesian belief networks, and statistical pattern recognition.

9. The method according to claim 1 wherein said step of outputting information further comprises (i) a step of selecting an utterance and an affect from one or more utterance tables in a manner responsive to said monitoring of said student during said current instructional session and to said stored information responsive to said monitoring of said student during previous instructional sessions, and (ii) a step of selecting a visual display from one or more tables of display behaviors in a manner responsive to said utterance, said affect, and said monitoring and said stored information.

10. The method according to claim 9 wherein said step of monitoring further comprises monitoring pedagogic information describing the pedagogic characteristics of said student, wherein said selected display behavior comprises one or more personae, and wherein said selected visual display is further responsive to said pedagogic information;

whereby said one or more personae present a life-like appearance individualized to said student's cognitive style.

11. The method according to claim 1 further comprising prior to said step of outputting a step of inputting at least one request of said student for guidance in said interactive instruction, and wherein said output information is further responsive to said input requests.

12. The method according to claim 1 wherein said computer accessed by said student is one computer of a plurality of computers interconnected by a network, and wherein said student can access any of said plurality of computers for an instructional session.

13. The method according to claim 1 wherein said output information further comprises an utterance, and wherein the step of outputting further comprises a step of selecting said

utterance from one or more candidate utterances, and a further step of outputting said utterance as text or speech.

14. The method according to claim 13 wherein said step of selecting further comprises selecting said one or more candidate utterance from one or more tables of utterances.

15. The method according to claim 14 wherein said one or more table of utterances comprise at least 1,000 utterances.

16. The method according to claim 13 wherein said one or more candidate utterances comprises at least 10 utterances.

17. The method according to claim 1 wherein said responsive output information further comprises a display behavior, and wherein the step of outputting further comprises a step of selecting said display behavior from one or more candidate display behaviors, and a further step of outputting said display behavior.

18. The method according to claim 17 wherein said step of selecting further comprises selecting one or more candidate display behaviors from one or more tables of display behaviors.

19. The method according to claim 18 wherein said one or more tables of display behaviors comprise at least 1,000 display behaviors.

20. The method according to claim 17 wherein said one or more candidate display behaviors comprises at least 10 display behaviors.

21. The method according to claim 17 wherein said step of outputting said selected display behavior comprises

outputting one or more modalities selected from the group consisting of text, voice, audio, animation, video, and preformatted animated sequences.

22. The method according to claim 17 wherein said selected display behavior comprises one or more persona.

23. The method according to claim 1 wherein said one or more materials is a plurality of materials.

24. The method according to claim 1 wherein said one or more students is a plurality of students.

25. The method according to claim 1 wherein said step of monitoring further comprises monitoring pedagogic information describing the pedagogic characteristics of said student in a manner independent of the subject matters of said one or more materials.

26. The method according to claim 1 wherein said step of monitoring further comprises monitoring progress and performance information describing the progress and performance of said student in said interactive instruction presented by each of said one or more materials.

27. The method according to claim 1 wherein said step of storing further comprises storing said information responsive to said monitoring in one of one or more student data objects, each student data object of said one or more student data objects being uniquely associated with exactly one student of said one or more students.

28. The method according to claim 1 wherein said one or more materials further comprise a material engine and one or more materials data, and wherein said step of presenting interactive instruction by executing one or more materials

further comprises executing said materials engine which references said one or more materials data.

29. The method according to claim 28 wherein said materials data further comprise notations, and wherein said step of monitoring further comprises said materials engine referencing said notations in order to generate monitoring information.

30. A method of operating an agent based instruction system for interactive instruction of one or more students, said method comprising:

(a) checking the authority of one of said students to access said system for interactive instruction by one or more materials at a computer, said computer being one computer of a plurality of computers interconnected by a network;

(b) loading to said computer software and data for said interactive instruction;

(c) executing said one or more materials on said computer for presenting interactive instruction to said one student; and

(d) outputting information on said computer to guide said student in said interactive instruction, said output information responsive to performance of said interactive instruction of said student.

31. The method according to claim 30 further comprising after said step of loading a further step of monitoring said interactive instruction, said monitoring generating monitoring information that monitors said interactive instruction of said student, and wherein said step of outputting information is responsive to said monitoring information;

whereby said system acts as a virtual tutor adapted to said one student, said virtual tutor for guiding said interactive instruction of said student.

32. The method according to claim 31 further comprising after said monitoring step a further step of controlling said one or more materials to present instruction to said student that is responsive to said monitoring information, whereby said interactive instruction presented by said system is individualized to said student.

33. The method according to claim 32 further comprising after said loading step a further step of maintaining a model of said one student, said maintaining responsive to said monitoring information of said student, and wherein the step of outputting and the step of controlling are further responsive to said model of said student, whereby said outputting step and said controlling step adapt to said student thereby individualizing said interactive instruction of said student.

34. The method according to claim 30 wherein said one or more materials comprise a plurality of materials.

35. The method according to claim 30 wherein one or more of said plurality of computers are configured as one or more server computers for holding databases of software and data, and said step of loading further comprises loading across said network to said computer from said databases.

36. The method according to claim 35 wherein said loading occurs when said software and data is demanded at said computer.

37. The method according to claim 35 further comprising caching read-only data on said computer.

38. The method according to claim 30 wherein said step of outputting information further comprises outputting information in one or more output modalities.

39. The method according to claim 38 where said one or more output modalities are one or more output modalities selected from the group consisting of text, graphics, speech, audio, animation, video, and preformatted animated sequences.

40. The method according to claim 38 wherein said step of outputting selects said output modalities to output one or more persona or personae responsive to said interactive instruction.

41. The method according to claim 38 wherein said output modalities further comprise content, and said step of outputting information further comprises a step of loading said content to said computer.

42. A method of operating an agent based instruction system for interactive instruction of one or more students over a plurality of instructional sessions, said method comprising:

(a) presenting interactive instruction to one of said students by executing one or more materials on a computer accessed by said student for a current instructional session;

(b) monitoring said interactive instruction of said student during said current instructional session;

(c) storing information responsive to said monitoring of said student during said current instructional session for use during subsequent instructional sessions;

(d) determining an affect responsive to said monitoring of said student during said current instructional session and to said stored information responsive to said monitoring of said student during previous instructional sessions; and

(e) outputting information on said computer to guide said student in said interactive instruction, said output information responsive to said affect, to said monitoring of said student during said current instructional

session, and to said stored information responsive to said monitoring of said student during previous instructional sessions, said output information comprising a visual display;

whereby said visual display is responsive to said affect and to said interactive instruction in a life-like manner.

43. The method according to claim 42 wherein said step of monitoring further comprises monitoring pedagogic characteristics of said student, and wherein the step of determining an affect determines an affect further responsive to said pedagogic characteristics;

whereby said visual display is responsive in a life-like manner individualized to said student's cognitive style.

44. The method according to claim 42 wherein said output information further comprises an utterance, and wherein the step of outputting further comprises a step of selecting said utterance from one or more tables of utterances in a manner responsive to said monitoring and to said stored information, and a further step of outputting said utterance as text or speech;

whereby said utterance and said visual display are responsive in a life-like manner.

45. The method according to claim 42 wherein said step of outputting further comprises selecting said visual display from one or more tables of visual displays in a manner responsive to said affect, to said monitoring, and to said stored information.

46. The method according to claim 42 wherein said selected display behavior comprises one or more persona.

47. An agent based instruction system for interactive instruction of one or more students, said system comprising:

(a) one or more computers having interactive input/output devices and interconnected by a network;

(b) one or more materials executable on said one or more computers, each said material for presenting interactive instruction to said one or more students and for generating monitoring information that monitors said interactive instruction; and

(c) one or more agents executable on said one or more computers, each said agent associated with exactly one of said students and each said student associated with exactly one of said agents, each said agent comprising

(i) action processing for controlling said one or more materials to instruct said associated student, said controlling being responsive to said monitoring information that monitors said interactive instruction of said associated student, and

(ii) behavior processing for outputting information to guide said associated student, said outputting being responsive to said monitoring information that monitors said interactive instruction of said associated student;

whereby said system acts as a virtual tutor to each of said students and said interactive instruction of each of said students is individualized to each student.

48. The system according to claim 47 further comprising executive software for interfacing said one or more materials and said one or more agents to said one or more computers and to said network.

49. The system according to claim 47 wherein said network is configured to permit any one of said students to access any one of said one or more materials from any one of said computers.

50. The system according to claim 47 wherein said network is configured to permit one or more of said computers to be located in one or more locations.

51. The system according to claim 50 wherein one or more of said locations are residences of one or more of said students.

52. The system according to claim 50 wherein one or more of said materials presents homework to one or more of said students.

53. The system according to claim 47 wherein said network is further configured to be a packet switched network.

54. The system according to claim 47 wherein said agent action processing is further responsive to a request for guidance from said associated student, and wherein said agent behavior processing is further responsive to said request for guidance.

55. The system according to claim 54 wherein said agent behavior processing further comprises (i) utterance generation processing for selecting an utterance and an affect responsive to said monitoring information or to said request for guidance, and (ii) visual display generation for selecting a visual display responsive to said utterance and said affect.

56. The system according to claim 55 wherein said agent behavior processing selects said utterance and said visual display to represent a persona, said selection being from a table of available personas and according to the preferences of said associated student.

57. The system according to claim 47 wherein said materials further comprise instructional materials executable on said computers for interactive instruction of said students, and tools executable on said computers for assistance of said students in said interactive instruction.

58. The system according to claim 57 wherein said instructional materials further comprise instructional materials appropriate to primary or secondary education.

59. The system according to claim 57 wherein said tools further comprise one or more tools selected from the group comprising a calculator, a dictionary, a thesaurus, an atlas, an encyclopedia, and a network search tool.

60. The system according to claim 57 wherein said tools further comprise a starfish tool for displaying and selecting relationships.

61. The system according to claim 47 further comprising one or more schedule/calendar tools executable on said computers, each said schedule/calendar tool associated with exactly one of said plurality of students and each said student associated with exactly one of said schedule/calendar tools, each said schedule/calendar tools for outputting to said associated student information relating to scheduled activities of said associated student, and for providing to said agent of said associated student information relating to scheduled activities of said associated student.

62. The system according to claim 61 further comprising data areas for each of said students characterizing scheduled activities according to deadline date and priority, and wherein said schedule/calendar tool further limits said associated student to interactive instruction according to said data areas characterizing said scheduled activities.

63. The system according to claim 47 further comprising one or more communication tools executable on said computers for providing forms of interactive group instruction to a group of said students, and for generating monitoring information that monitors said group instruction of each student in said group.

64. The system according to claim 63 where said forms of group instruction are selected from the group consisting of exchange of messages, group work on a shared material, and group participation in educational contests.

65. The system according to claim 47 wherein one or more of said materials further comprises materials engine software and materials data, and wherein said materials engine process said materials data to present said interactive instruction.

66. The system according to claim 65 wherein each of said materials data further comprises:

(a) a plurality of display objects for presentation;

(b) sequencing logic for controlling the order of said presentation of said plurality of display objects; and

(c) notations for causing generation of said monitoring information.

67. The system according to claim 47 wherein one or more of said materials comprises a program having data and instructions.

68. The system according to claim 47 further comprising pedagogic information data areas for each student, said pedagogic information data areas comprising data for a pedagogic model of said student, and wherein said agent action processing and said agent behavior processing is further responsive to said pedagogic information data areas.

69. The system according to claim 68 wherein said data in said pedagogic information data areas does not depend on the subject matter of said one or more materials.

70. The system according to claim 68 wherein said agent action processing updates said pedagogic information data areas associated with said agent's associated student, said updating being responsive to said monitoring information, whereby said associated agent adapts to said student.

71. The system according to claim 68 further comprising progress and performance data areas for each student, said progress and performance data areas comprising data describing progress and performance of each said student in said interactive instruction, and wherein said agent action processing and said agent behavior processing are further responsive to said progress and performance information data areas.

72. The system according to claim 71 wherein said agent action processing updates said progress and performance data areas associated with said associated student of said agent, said updating responsive to said monitoring information; whereby said associated agent adapts to said student.

73. The system according to claim 47 wherein one or more of said materials presents said interactive instruction according to an education paradigm, and wherein said monitoring information generated by said materials further comprises pedagogic information classified according to said education paradigm of said materials.

74. The system according to claim 73 further comprising control parameters for each material that have an educational paradigm, wherein each material presents said interactive instruction according to values of said control parameters,

and wherein said agent action processing assigns said values of said control parameters;

whereby said agent action processing controls said materials.

75. The system according to claim 73 wherein said educational paradigm is selected from the group consisting of interactive tutorial, fluency exercise, paired association exercise, discrimination formation exercise, and simulation exercise.

76. The system according to claim 73 wherein said educational paradigm is standardized according to an instructional context and an instructional format.

77. The system according to claim 76 wherein said instructional context is selected from the group consisting of prerequisite test, prerequisite review, pretest, new material introduction, new material discrimination, new material review, fluency exercise practice, review practice, and unit mastery test.

78. The system according to claim 76 wherein said instructional format is selected from the group consisting of multiple choice, unprompted fill-in-the-blank, fill-in-the-blank selected from a list, paired associates by letter, paired associates by dragging, paired associates by matching, computation, simulation to identify parts of figures or text, and simulation game.

79. The system according to claim 47 wherein said agent action processing generates at least one action responsive to said monitoring information.

80. The system according to claim 79 wherein said agent action processing further comprises software using one or more techniques selected from the group of expert systems,

neural networks, Bayesian belief networks, and statistical pattern recognition.

81. The system according to claim 79 further comprising a plurality of tables of rules, and wherein said agent action processing software further comprises software referencing said plurality of tables of rules in order to control said one or more materials and to generate said action(s).

82. The system according to claim 81 wherein said plurality of tables of rules comprises a policy filter table, a decision weight table, and a selection criteria table, and wherein said agent action processing references said policy filter table for determining one or more candidate actions, references said decision weight table for ranking said one or more candidate actions, and references said selection criteria table for selecting said action(s) from said ranked candidate actions.

83. The system according to claim 79 wherein said agent behavior processing is responsive to said action(s) in order to output information responsive to said monitoring information.

84. The system according to claim 83 further comprising a plurality of tables of possible outputs, and wherein said agent behavior processing software references said tables of possible outputs.

85. The system according to claim 84 wherein said one or more tables of possible outputs further comprise an utterance template table and a display behavior table, and wherein said agent behavior processing references said utterance template table for selecting an utterance and an affect according to said action(s), and references said display behavior table for selecting a visual display according to said action(s), said utterance, and said affect.

86. The system according to claim 83 wherein said agent behavior processing outputs information in a plurality of output modalities.

87. The system according to claim 83 wherein said output modalities are one or more output modalities selected from the group consisting of text, graphics, speech, audio, animation, video, and preformatted animated sequences.

88. The system according to claim 47 further comprising one or more student data objects, each of said student data objects associated with exactly one student, and wherein each agent stores information reflecting said monitoring information of said one student associated with said agent in said one student data object associated with said associated student.

89. The system according to claim 88 wherein said student data object associated with one student further comprises:

(a) pedagogic information describing a pedagogic model of said one student; and

(b) progress and performance information for describing the progress and performance of said student in said materials.

90. The system according to claim 89 wherein said agent associated with each student further comprises agent software and said student data object associated with said student, and wherein said agent software references and updates said associated student data object.

91. The system according to claim 47 wherein one or more of said computers are configured as server systems, wherein said server systems store said one or more materials and one or more agents, and wherein said one or more computers downloads said materials and said one or more

agents from said one or more server systems across said computer network.

92. The system according to claim 91 further comprising databases of pedagogic information and materials progress and performance information for said one or more students, and wherein said databases are stored on said server systems.

93. The system according to claim 92 further comprising reporting software for generating reports from said databases of pedagogic information and materials progress and performance information for said one or more students.

94. The system according to claim 47 further comprising one or more system managers executable on said one or more computers, wherein said interactive input/output devices include a computer display at each of said one or more computers, and wherein said system manager executing on one computer partitions said display of said one computer into one or more display areas.

95. The system according to claim 94 wherein said one or more display areas are selected from the group comprising an agent area for agent interactivity, a materials area for materials interactivity, and a system area in which said system manager displays selection icons for available system tools and facilities.

96. The system according to claim 95 wherein said one or more materials and said one or more agents provide facilities always available to said one or more students and said materials area and said agent area comprise sub-areas whose selection activates one of said always available facilities.

97. The system according to claim 95 wherein said one or more display areas change in size from time to time.

98. The system according to claim 47 wherein one or more teachers directs instruction of one or more of said students, said system further comprising:

(a) one or more teacher materials executable on said one or more computers, each said teacher material for presenting interactive instruction to teachers in the use of said system and in the use of materials directed to said students and for generating monitoring information that monitors said interactive instruction; and

(b) one or more teacher agents executable on said one or more computers, each said teacher agent associated with exactly one of said teachers and each said teacher associated with exactly one of said agents, each said agent comprising

(i) action processing for controlling said one or more materials to instruct said associated teacher, said controlling being responsive to said monitoring information that monitors said interactive instruction of said associated teacher, and

(ii) behavior processing for outputting information to guide said associated teacher, said outputting being responsive to said monitoring information that monitors said interactive instruction of said associated teacher.

99. An agent based instruction system for interactive instruction of one or more students, said system comprising:

(a) one or more computers having interactive input/output devices and interconnected by a network;

(b) one or more materials executable on said one or more computers, each said material for presenting interactive instruction to said one or more students and for generating monitoring information that monitors said interactive instruction; and

(c) one or more agents executable on said one or more computers, each said agent associated with exactly one of said students and each said student associated with exactly one or said agents, each said agent comprising

(i) utterance generation processing for selecting an affect and an utterance to guide said one associated student, said selecting of said affect and said utterance being responsive to said monitoring information that monitors said interactive instruction of said one associated student, and

(ii) visual display generation for selecting a visual display to guide said one associated student, said selecting of said visual display being responsive to said affect, to said utterance, and to said monitoring information that monitors said interactive instruction of said associated student, and

(iii) output processing for outputting to said associated student said selected utterance and said selected visual display;

whereby said selected visual display and said selected utterance are responsive to said affect and to said interactive instruction in a life-like manner.

100. The system according to claim 99 wherein said monitoring information further comprises pedagogic information describing the pedagogic characteristics of said associated student, and wherein utterance generation processing selects an affect further responsive to said pedagogic information;

whereby said selected visual display and said selected utterance are further responsive in a manner individualized to a cognitive style of said associated student.

101. The system according to claim 99 wherein said utterance generation processing selects said affect and said utterance from one or more tables of utterances.

102. The system according to claim 99 wherein said visual display processing selects said visual display from one or more tables of visual displays.

103. The system according to claim 99 wherein said selected visual display comprises one or more persona.

104. The system according to claim 99 further comprising action processing for generating at least one action and for controlling said one or more materials to instruct said associated student, said generating and said controlling being responsive to said monitoring information that monitors said interactive instruction of said associated student, and wherein said utterance generation processing and said visual display selection processing are further responsive to said action(s).

105. A method of operating an agent based instruction system for instruction of a plurality of students, said method comprising:

(a) executing one or more materials on a computer for presenting interactive instruction to one student of said plurality of students, said computer being one computer of a plurality of computers interconnected by a network, each computer of said plurality having interactive input/output devices;

(b) generating monitoring information that monitors said interactive instruction presented to said student; and

(c) controlling said one or more materials to instruct said student, said controlling being responsive to said information monitoring the interactive instruction of said student;

whereby said interactive instruction is individualized to each student of said plurality of students.

106. The method according to claim 105 further comprising after said step of generating a further step of outputting information on said computer to guide said student in said interactive instruction, said outputting information

responsive to said monitoring information of said interactive instruction of said student;

whereby said system acts as a virtual tutor adapted to said student, said virtual tutor for guiding said interactive instruction of said student.

107. The method according to claim ? wherein said output information further comprises one or more persona.

108. The method according to claim ? wherein said step of outputting information further comprises outputting information in a plurality of output modalities.

109. The method according to claim 108 wherein said output modalities are one or more output modalities selected from the group consisting of text, graphics, speech, audio, animation, video, and preformatted animated sequences

110. The method according to claim ? wherein said step of outputting information further comprises (i) a step of selecting an utterance and an affect from one or more utterance tables in a manner responsive to said controlling step and (ii) a step of selecting a visual display from one or more tables of display behaviors in a manner responsive to said utterance, said affect, and said controlling step.

111. The method according to claim ? further comprising prior to said outputting step a further step of inputting student requests for guidance in said interactive instruction, and wherein said step of outputting information is further responsive to said student requests.

112. The method according to claim 105 wherein said one or more materials is a plurality of materials.

113. The method according to claim 105 further comprising prior to said executing step a further step of

accessing any one of said computers by said one student, said accessing comprising verifying the authority of said one student to access said system for interactive instruction by said one or more materials.

114. The method according to claim 113 wherein one or more of said computers are located in a plurality of locations, and wherein the step of accessing further comprises accessing any of said computers in plurality of locations.

115. The method according to claim 114 wherein one or more of said plurality of locations are residences of one or more of said students, and wherein said one or more materials presents homework in said one or more residences.

116. The method according to claim 105 wherein said step of controlling further comprises controlling according to one or more tables of rules.

117. The method according to claim 116 wherein said one or more tables of rules further comprise a policy filter table, a decision weight table, and a selection criteria table, and wherein said controlling step controls said one or more materials according to one or more determined controlling actions, and wherein said controlling step references said policy filter table for determining one or more candidate controlling actions, references said decision weight table for ranking said one or more candidate controlling actions, and references said selection criteria table for selecting one or more controlling actions from said ranked candidate controlling actions.

118. The method according to claim 105 wherein said step of controlling further comprises controlling according to one or more methods selected from the group consisting of expert

systems, neural networks, Bayesian belief networks, and statistical pattern recognition.

119. The method according to claim 105 wherein the step of executing further comprises executing one or more of said one or more materials according to an educational paradigm, and wherein said monitoring information further comprises pedagogic information classified according to said educational paradigm adopted by said one or more materials.

120. The method according to claim 119 wherein said educational paradigm is standardized according to an instructional context and an instructional format.

121. The method according to claim 105 further comprising after said generating step a further step of updating one student model of a plurality of student models, each student of said plurality of students being associated with exactly one student model, said updating being responsive to the information monitoring the interactive instruction of said student, and wherein the step of controlling said one or more materials to instruct said student is further responsive to said student model of said student;

whereby said one or more materials are individualized to said student.

122. The method according to claim 121 wherein said step of updating further comprises updating pedagogic information in said student model, said pedagogic information describes pedagogic characteristics of said student of said plurality of students in a manner independent of the subject matters of said one or more materials.

123. The method according to claim 121 wherein said step of updating further comprises updating progress and performance information in said student model, said progress

and performance information describes the progress and performance of said student in said interactive instruction presented by each of said one or more materials.

124. The method according to claim 105 wherein said one or more materials further comprises one or more instructional materials for presenting interactive instruction to said plurality of students, and one or more tools for presenting interactive assistance to said plurality of students during said interactive instruction.

125. The method according to claim 105 further comprising prior to said controlling step (i) a step of executing one scheduler/calendar tools of a plurality of scheduler/calendar tools, each student of said plurality of students being associated with exactly one scheduler/calendar tool, said one scheduler/calendar tool providing said student with information relating to scheduled activities of said student, and (ii) a step of generating monitoring information that monitors said scheduled activities of said student.

126. The method according to claim 125 wherein the step of executing executes one or more materials that relate to said scheduled activities of said student.

127. The method according to claim 105 further comprising prior to said controlling step (i) a step of executing one or more communication tools for presenting one or more forms of group instruction to a group of students, said group including said student, and (ii) a step of generating monitoring information that monitors said group instruction of said student.

128. A method of operating an agent based instruction system for instruction of a plurality of students, said method comprising:

(a) a step for executing one or more materials on a computer for presenting interactive instruction to each student, said computer being one computer of a plurality of computers interconnected by a network, each computer of said plurality having interactive input/output devices;

(b) a step for generating monitoring information that monitors said interactive instruction presented to each student of said plurality of students;

(c) a step for controlling said one or more materials to instruct each student, said controlling being responsive to said information monitoring the interactive instruction of each student; and

(d) a step of outputting information to each student in order to guide each student in said interactive instruction, said outputting step responsive to said information monitoring the interactive instruction of each student and responsive to said controlling step;

whereby said interactive instruction is individualized to each student of said plurality of students and acts as a virtual tutor individualized to each student.

129. An agent based instruction system for instruction of a plurality of students, said system comprising:

(a) means for presenting interactive instruction to each student by one or more materials;

(b) means for generating monitoring information that monitors said interactive instruction presented to each student;

(c) means for controlling said one or more materials to instruct each student, said controlling being responsive to said information monitoring the interactive instruction of each student; and

(d) means for outputting information to each student in order to guide each student in said interactive instruction, said means for outputting being responsive to said information monitoring the interactive instruction of each student and responsive to said means for controlling;

whereby said interactive instruction is individualized to each student and said acts as a virtual tutor individualized to each student.

130. An agent based instruction system for instruction of a student, said system comprising:

(a) one or more materials executable on a computer for presenting interactive instruction to said student, said computer having interactive input/output devices; and

(b) an agent executable on said computer, said agent (i) receiving monitoring information from each of said one or more materials that monitors said interactive instruction of said student, (ii) controlling said one or more materials to instruct said student, said controlling being responsive to said monitoring information, and (iii) outputting information to guide said student, said outputting being responsive to said monitoring information.

131. A system for agent-based, interactive instruction of one or more students over a plurality of instructional sessions, said system comprising:

(a) means for presenting interactive instruction to one of said students by executing one or more materials on a computer accessed by said student for a current instructional session;

(b) means for monitoring said interactive instruction of said student during said current instructional session;

(c) means for storing information responsive to said monitoring of said student during said current instructional session for use during subsequent instructional sessions; and

(d) means for outputting information on said computer to guide said student in said interactive instruction, said output information responsive to said monitoring of said student during said current instructional session and to said stored information responsive to said

monitoring of said student during previous instructional sessions;

whereby said system acts as a virtual tutor adapted to said student, said virtual tutor for guiding said interactive instruction of said student.

132. A system for agent-based, interactive instruction of one or more students over a plurality of instructional sessions, said system comprising:

(a) means for presenting interactive instruction to one of said students by executing one or more materials on a computer accessed by said student for a current instructional session;

(b) means for monitoring said interactive instruction of said student during said current instructional session;

(c) means for storing information responsive to said monitoring of said student during said current instructional session for use during subsequent instructional sessions;

(d) means for determining an affect responsive to said monitoring of said student during said current instructional session and to said stored information responsive to said monitoring of said student during previous instructional sessions; and

(e) means for outputting information on said computer to guide said student in said interactive instruction, said output information responsive to said affect, to said monitoring of said student during said current instructional session, and to said stored information responsive to said monitoring of said student during previous instructional sessions, said output information comprising a visual display;

whereby said visual display is responsive to said affect and to said interactive instruction in a life-like manner.

133. A computer readable medium comprising instructions for performing the method of claim 1.

134. A computer readable medium comprising instructions for performing the method of claim 30.

135. A computer readable medium comprising instructions for performing the method of claim 42.

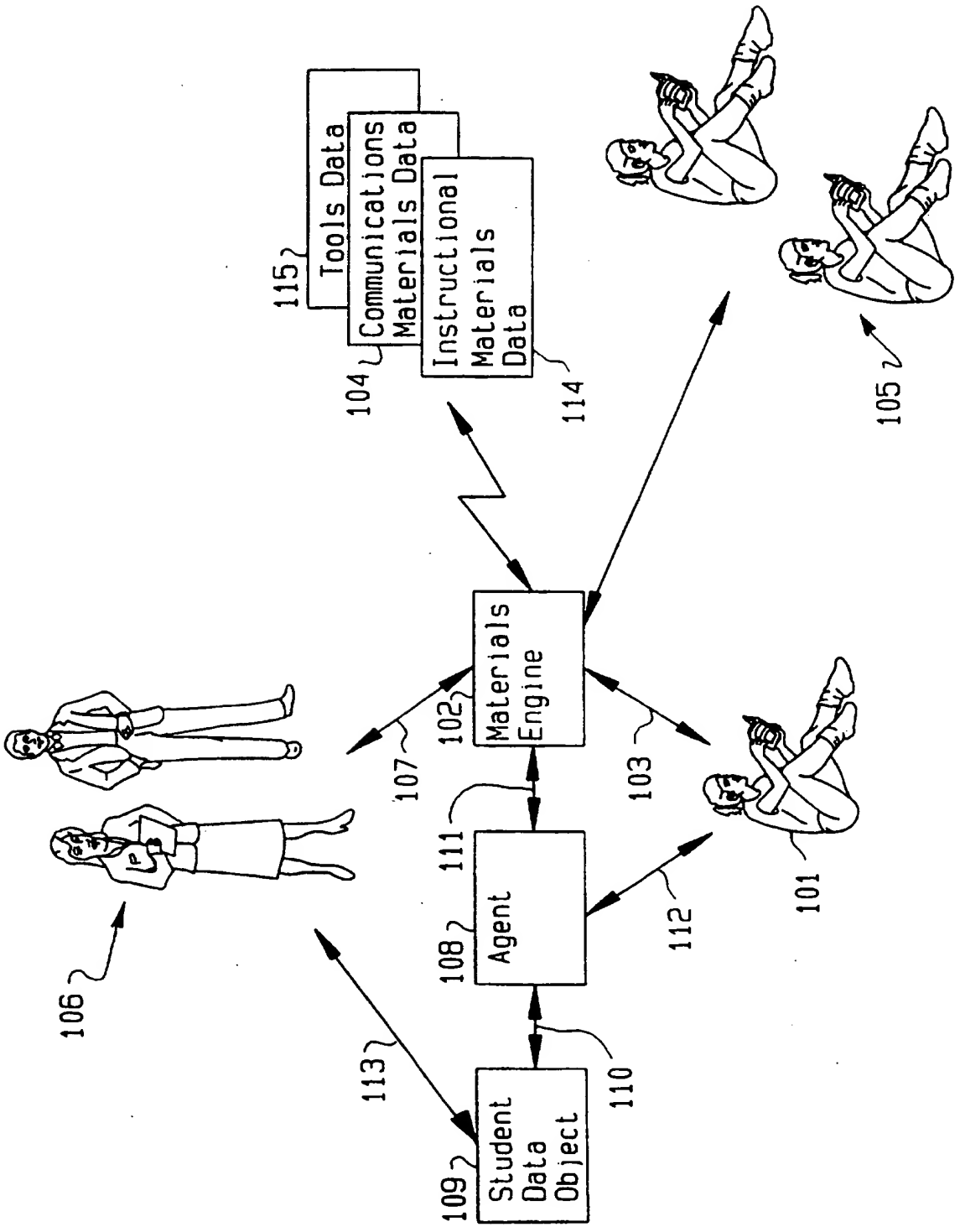
Tools Data
Communications Materials Data
Instructional Materials Data
115
104
114
105
Materials Engine
102
107
103
101
111
Agent
108
112
106
113
110
Student Data Object
109

FIG. 1

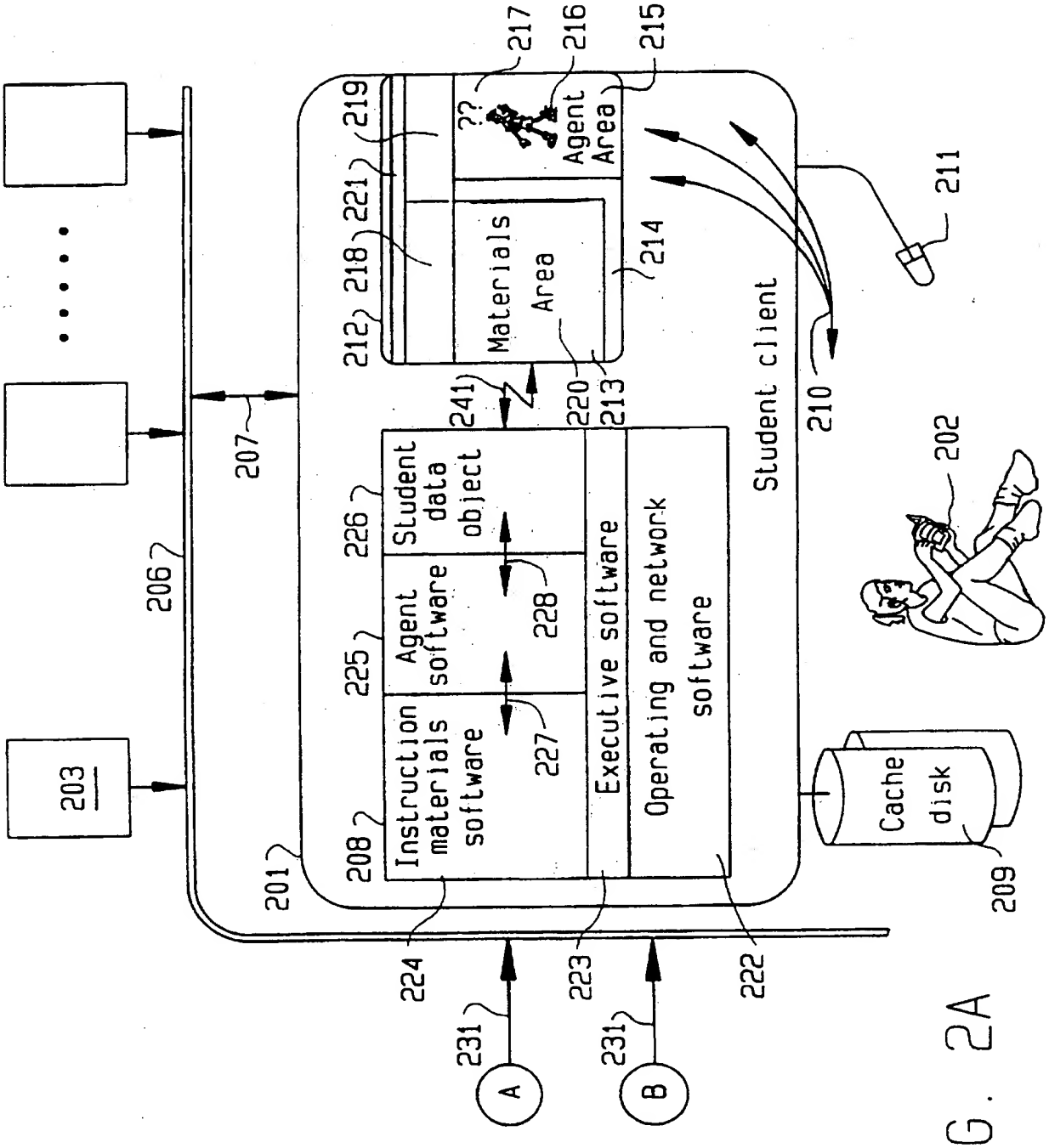
203
206
207
201
208
Instruction materials software
225
Agent software
227
228
226
Student data object
Executive software
Operating and network software
224
223
222
231
231
A
B
212
218
221
219
217
216
215
??
Agent Area
Materials Area
214
241
220
213
Student client
210
211
202
Cache disk
209

FIG. 2A

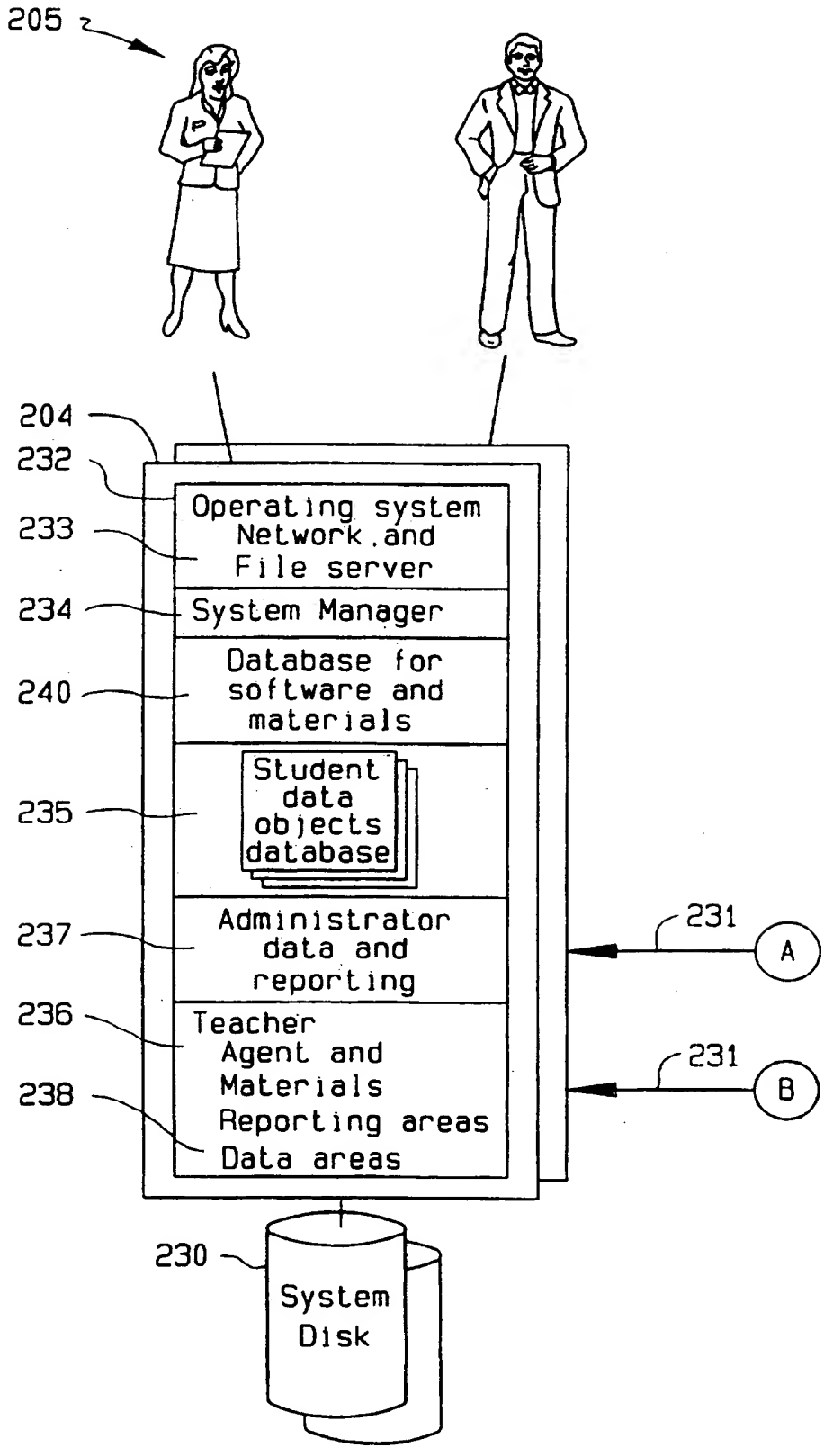
205
204
232
Operating system
Network and
File server
233
System Manager
234
Database for
software and
materials
240
Student
data
objects
database
235
Administrator
data and
reporting
237
231
A
Teacher
Agent and
Materials
Reporting areas
Data areas
236
238
231
B
230
System
Disk

FIG. 2B

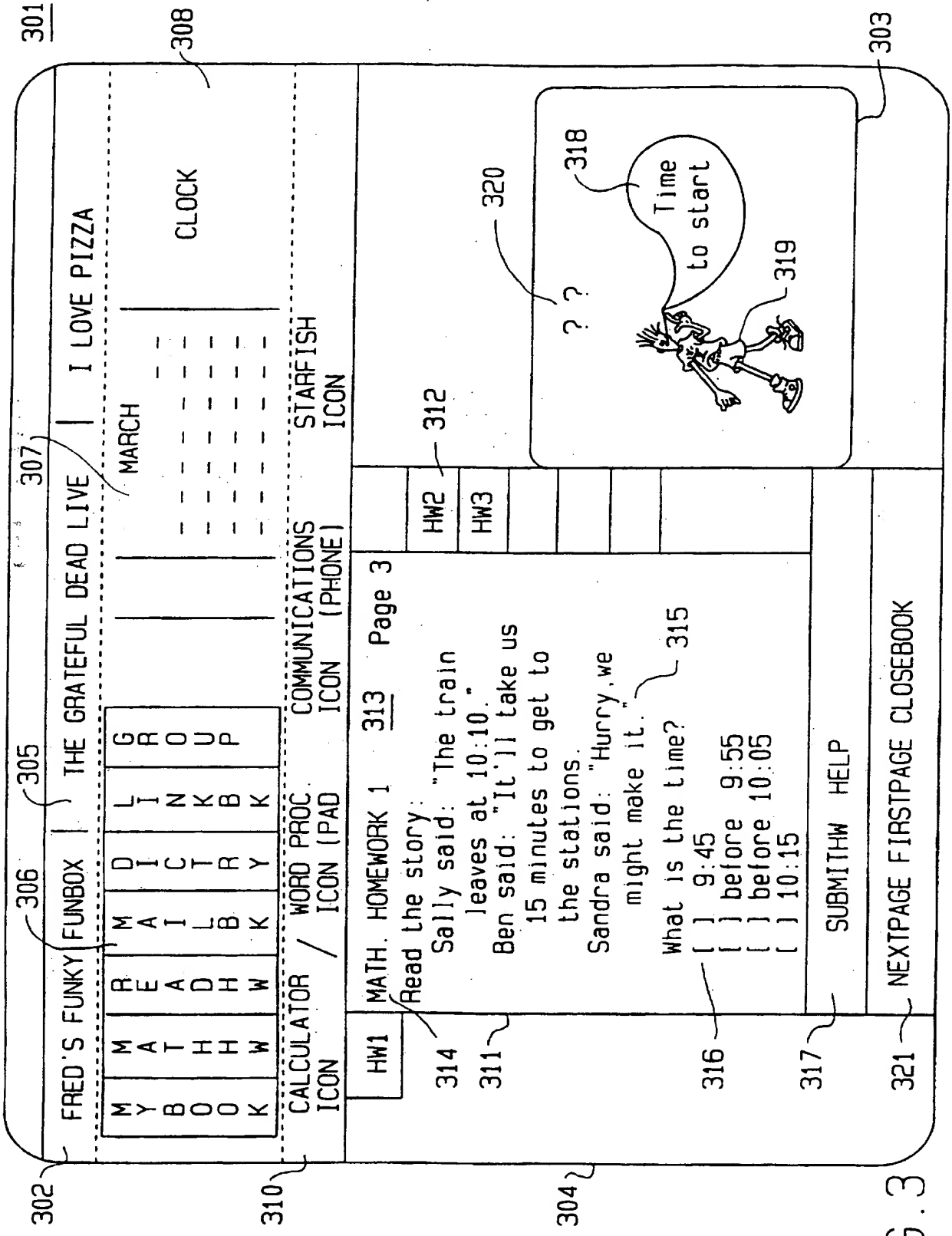
301
303
308
307
305
306
FRED'S FUNKY FUNBOX
I LOVE PIZZA
THE GRATEFUL DEAD LIVE
MARCH
CLOCK
MY BOOK
MEAL TIME
CALCULATOR ICON
WORD PROC. ICON (PAD
COMMUNICATIONS ICON (PHONE)
STARFISH ICON
HW1
MATH. HOMEWORK 1 313 Page 3
Read the story:
Sally said: "The train leaves at 10:10."
Ben said: "It'll take us 15 minutes to get to the stations.
Sandra said: "Hurry, we might make it."
What is the time?
[ ] 9:45
[ ] before 9:55
[ ] before 10:05
[ ] 10:15
HW2
HW3
312
320
318
Time to start
319
? ?
SUBMITHW HELP
NEXTPAGE FIRSTPAGE CLOSEBOOK
302
310
304
314
311
316
315
317
321

FIG. 3

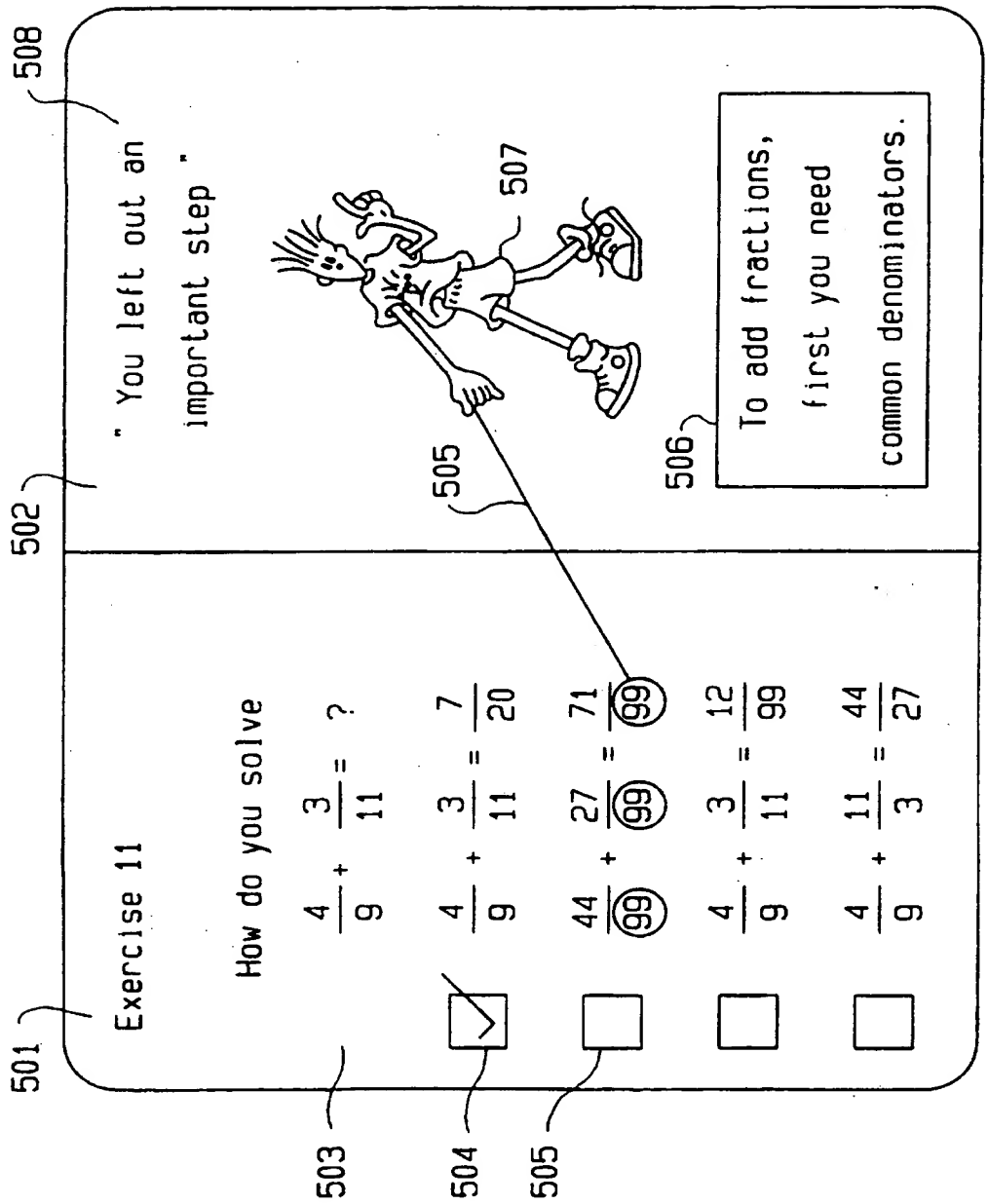
508
" You left out an important step "
507
502
505
506
To add fractions, first you need common denominators.
501
Exercise 11
How do you solve
4/9 + 3/11 = ?
4/9 + 3/11 = 7/20
44/99 + 27/99 = 71/99
4/9 + 3/11 = 12/99
4/9 + 11/3 = 44/27
503
504
505

FIG. 4

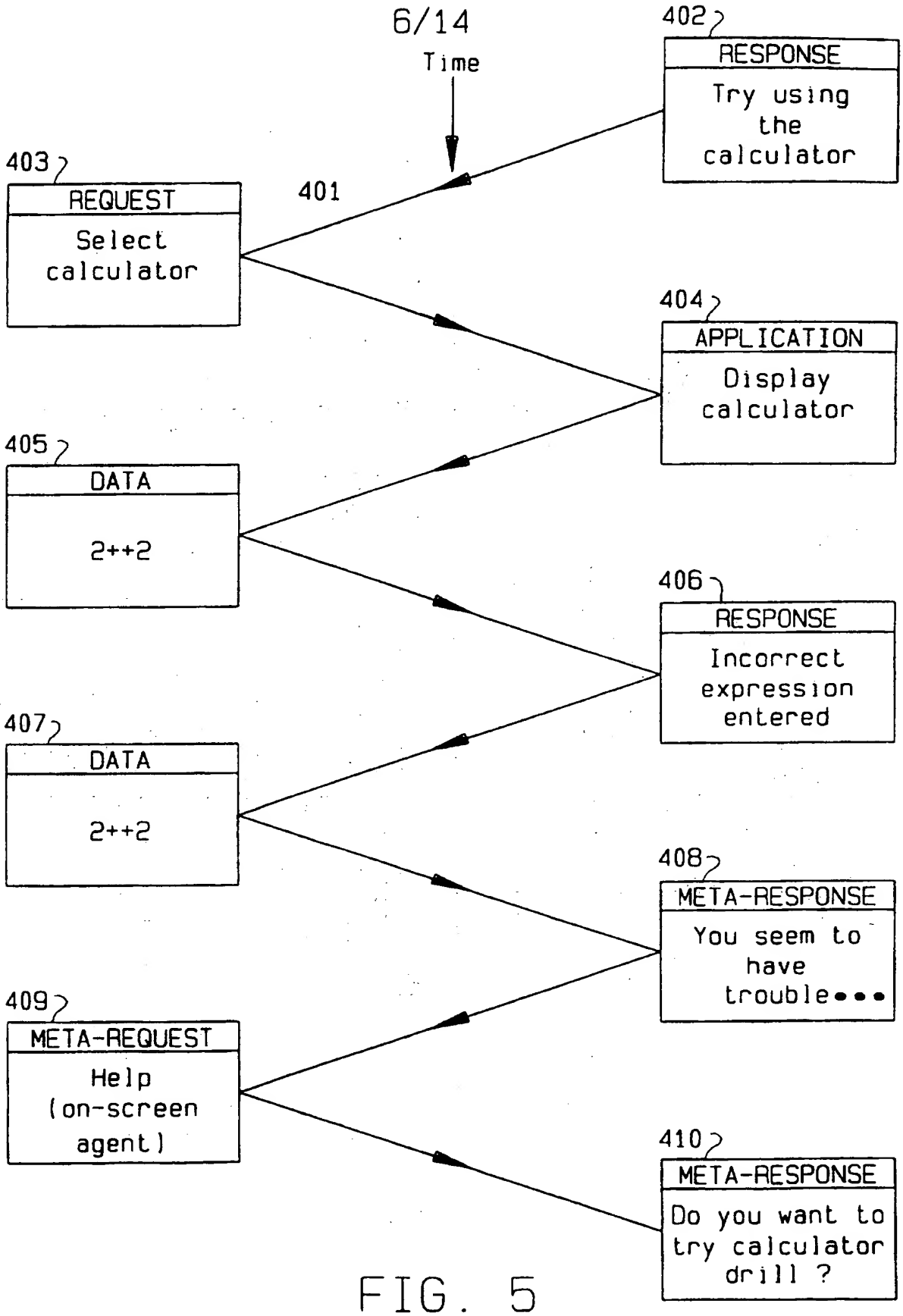
Time
401
402
RESPONSE
Try using the calculator
403
REQUEST
Select calculator
404
APPLICATION
Display calculator
405
DATA
2++2
406
RESPONSE
Incorrect expression entered
407
DATA
2++2
408
META-RESPONSE
You seem to have trouble•••
409
META-REQUEST
Help (on-screen agent)
410
META-RESPONSE
Do you want to try calculator drill ?

FIG. 5

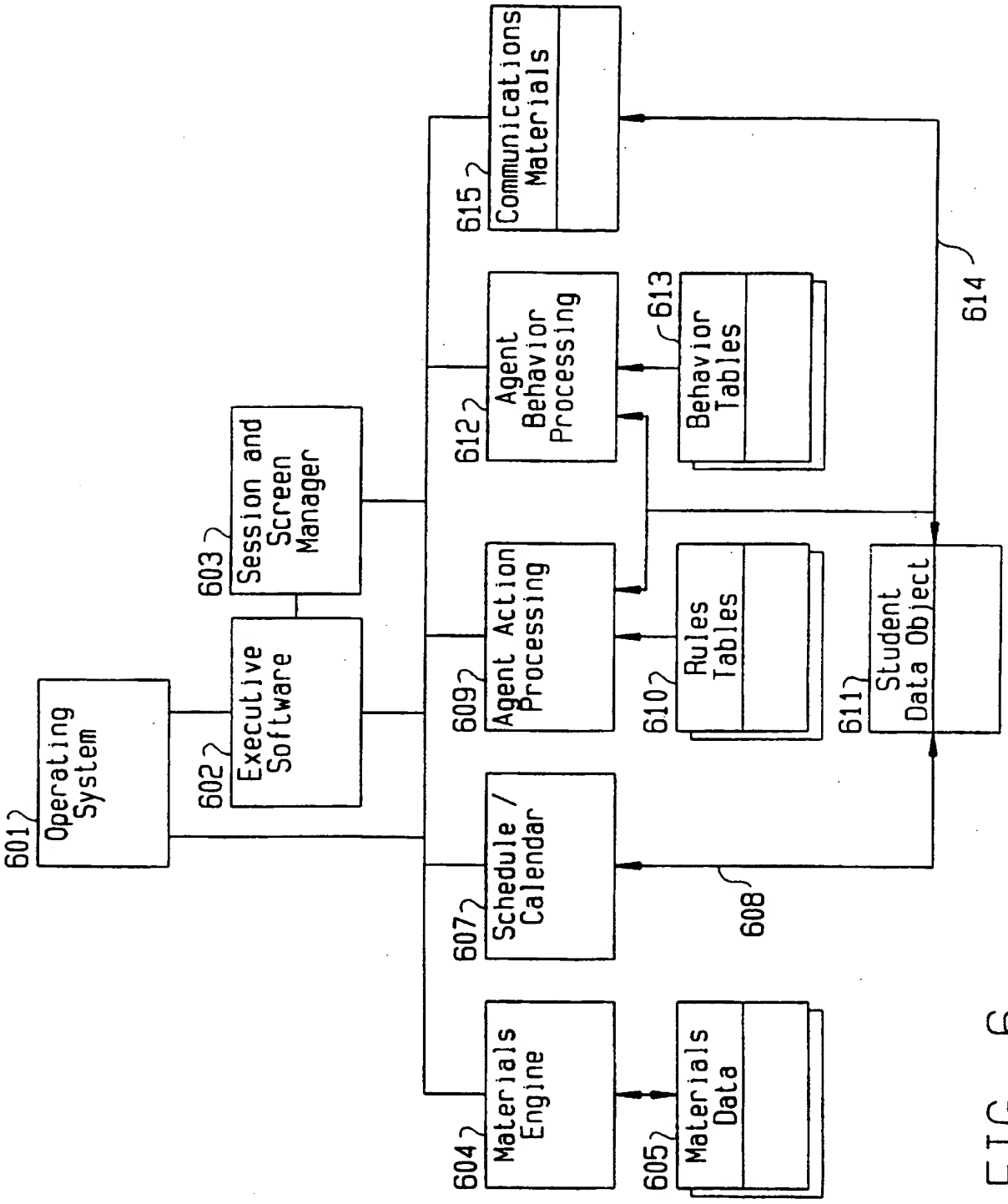
601
Operating System
602
Executive Software
603
Session and Screen Manager
604
Materials Engine
605
Materials Data
607
Schedule / Calendar
608
609
Agent Action Processing
610
Rules Tables
611
Student Data Object
612
Agent Behavior Processing
613
Behavior Tables
614
615
Communications Materials

FIG. 6

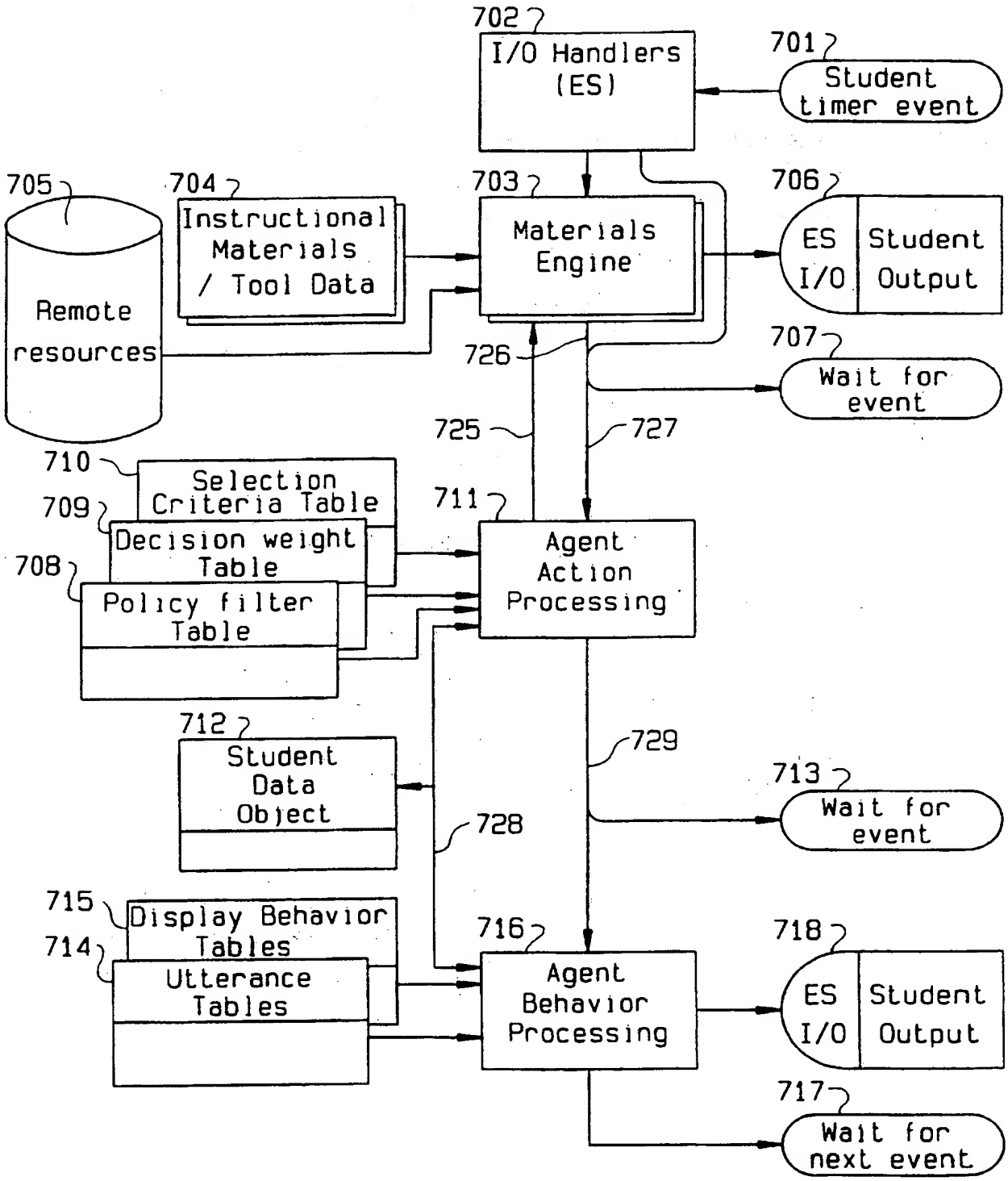
702
I/O Handlers (ES)
701
Student timer event
705
Remote resources
704
Instructional Materials / Tool Data
703
Materials Engine
706
ES I/O
Student Output
726
707
Wait for event
725
727
710
Selection Criteria Table
709
Decision weight Table
711
Agent Action Processing
708
Policy filter Table
712
Student Data Object
729
713
Wait for event
728
715
Display Behavior Tables
714
Utterance Tables
716
Agent Behavior Processing
718
ES I/O
Student Output
717
Wait for next event

FIG. 7

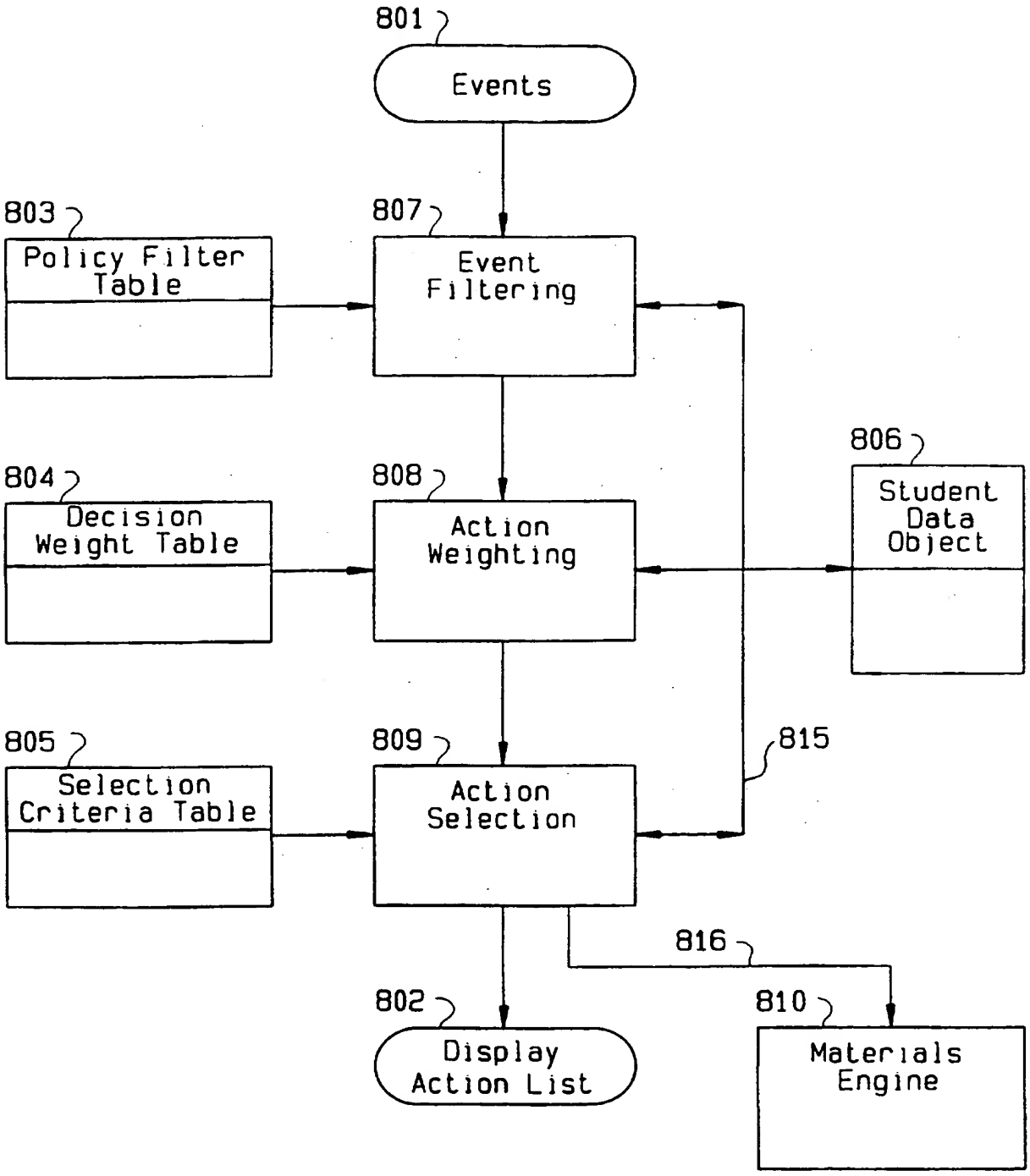
801
Events
803
Policy Filter Table
807
Event Filtering
804
Decision Weight Table
808
Action Weighting
806
Student Data Object
805
Selection Criteria Table
809
Action Selection
815
816
802
Display Action List
810
Materials Engine

FIG. 8

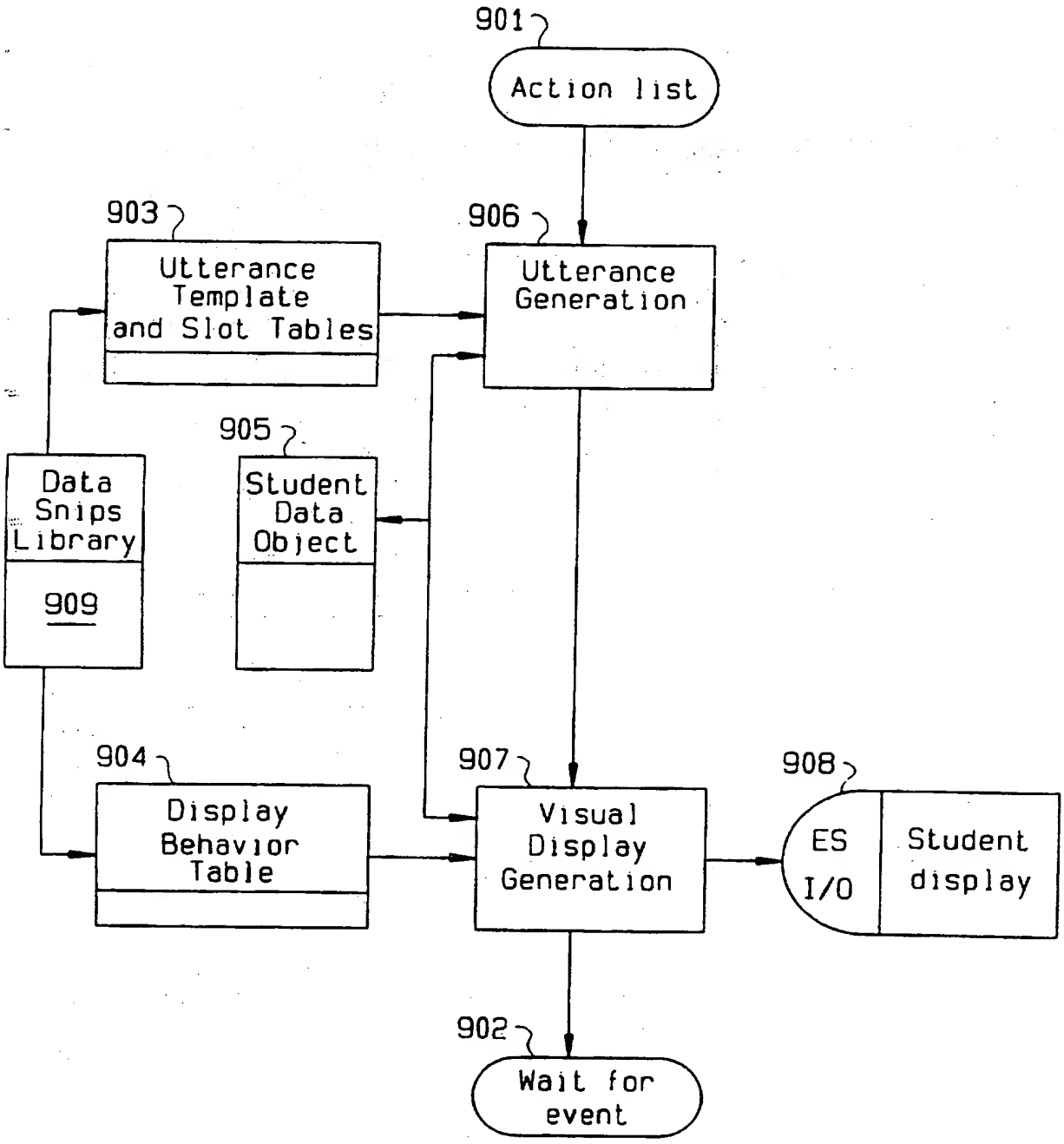
901
Action list
903
Utterance Template and Slot Tables
906
Utterance Generation
905
Data Snips Library
909
Student Data Object
904
Display Behavior Table
907
Visual Display Generation
908
ES I/O
Student display
902
Wait for event

FIG. 9

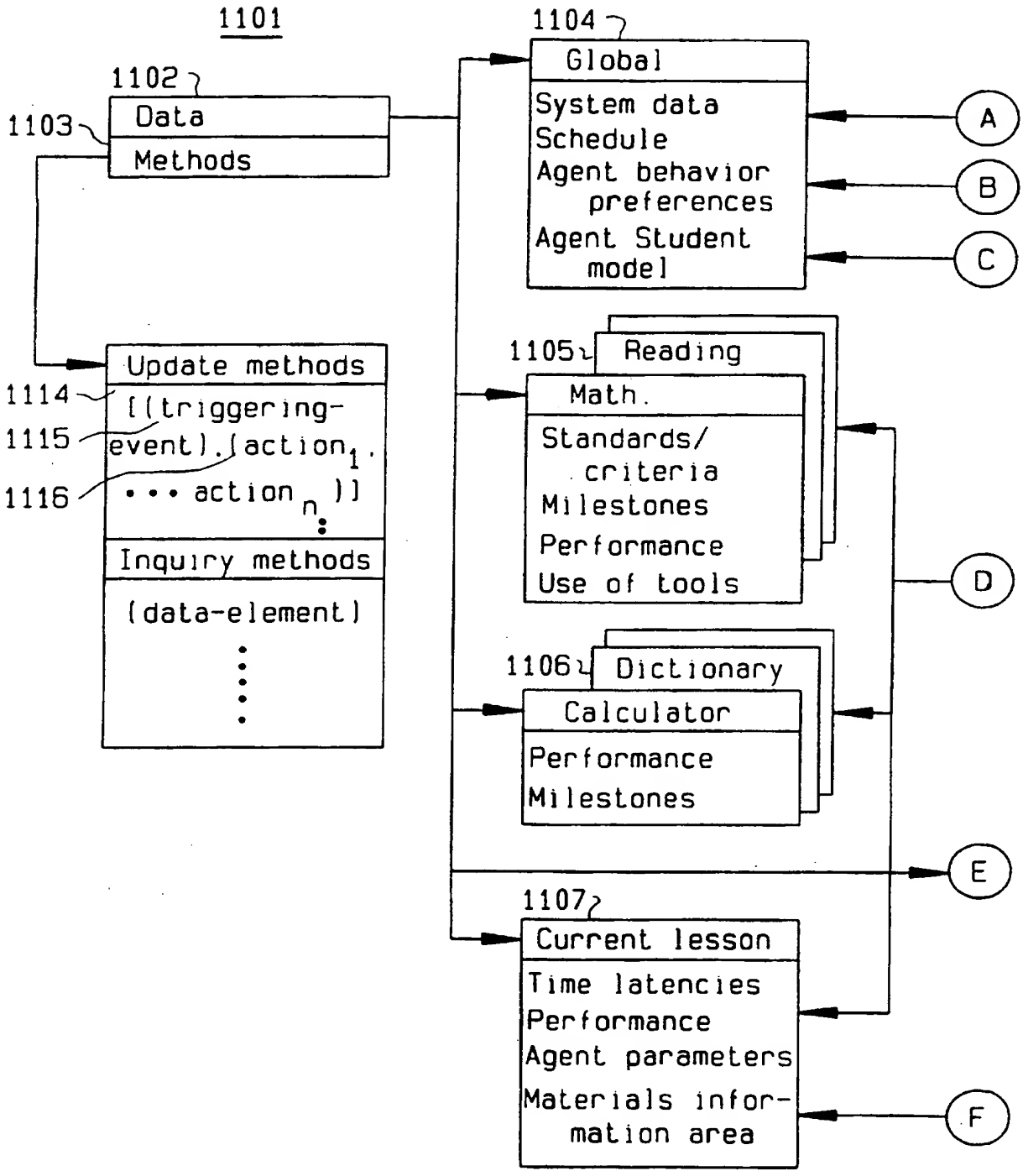
1101
1102
1103
Data
Methods
1104
Global
System data
Schedule
Agent behavior preferences
Agent Student model
A
B
C
Update methods
1114
[(triggering-
1115
event).[action1.
1116
• • • actionn]]
Inquiry methods
(data-element)
1105
Reading
Math.
Standards/ criteria
Milestones
Performance
Use of tools
D
1106
Dictionary
Calculator
Performance
Milestones
E
1107
Current lesson
Time latencies
Performance
Agent parameters
Materials infor-mation area
F

FIG. 10A

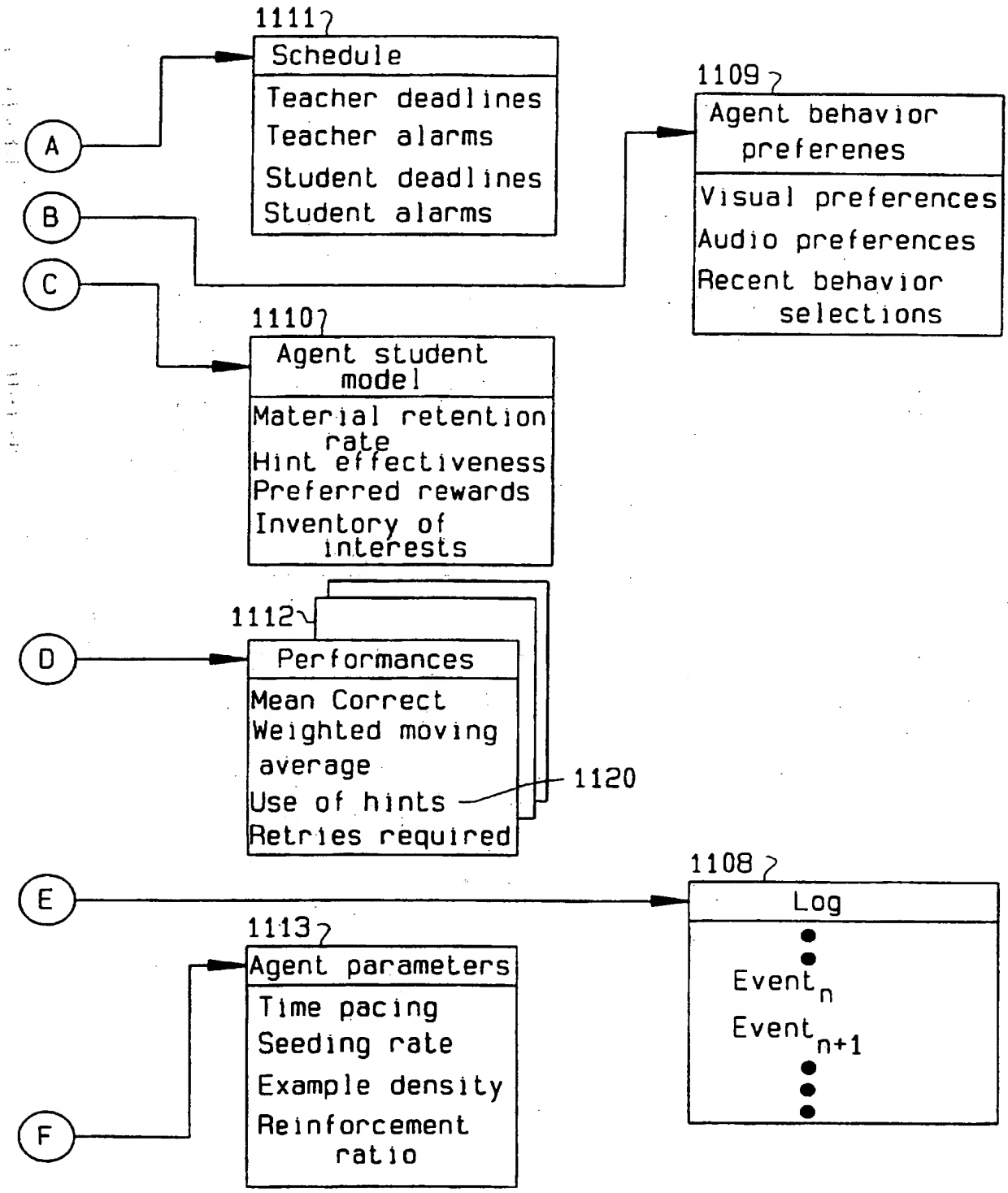
1111
Schedule
Teacher deadlines
Teacher alarms
Student deadlines
Student alarms
1109
Agent behavior preferenes
Visual preferences
Audio preferences
Recent behavior selections
A
B
C
1110
Agent student model
Material retention rate
Hint effectiveness
Preferred rewards
Inventory of interests
1112
Performances
Mean Correct
Weighted moving average
Use of hints
Retries required
1120
D
E
1108
Log
Event n
Event n+1
1113
Agent parameters
Time pacing
Seeding rate
Example density
Reinforcement ratio
F

FIG. 10B

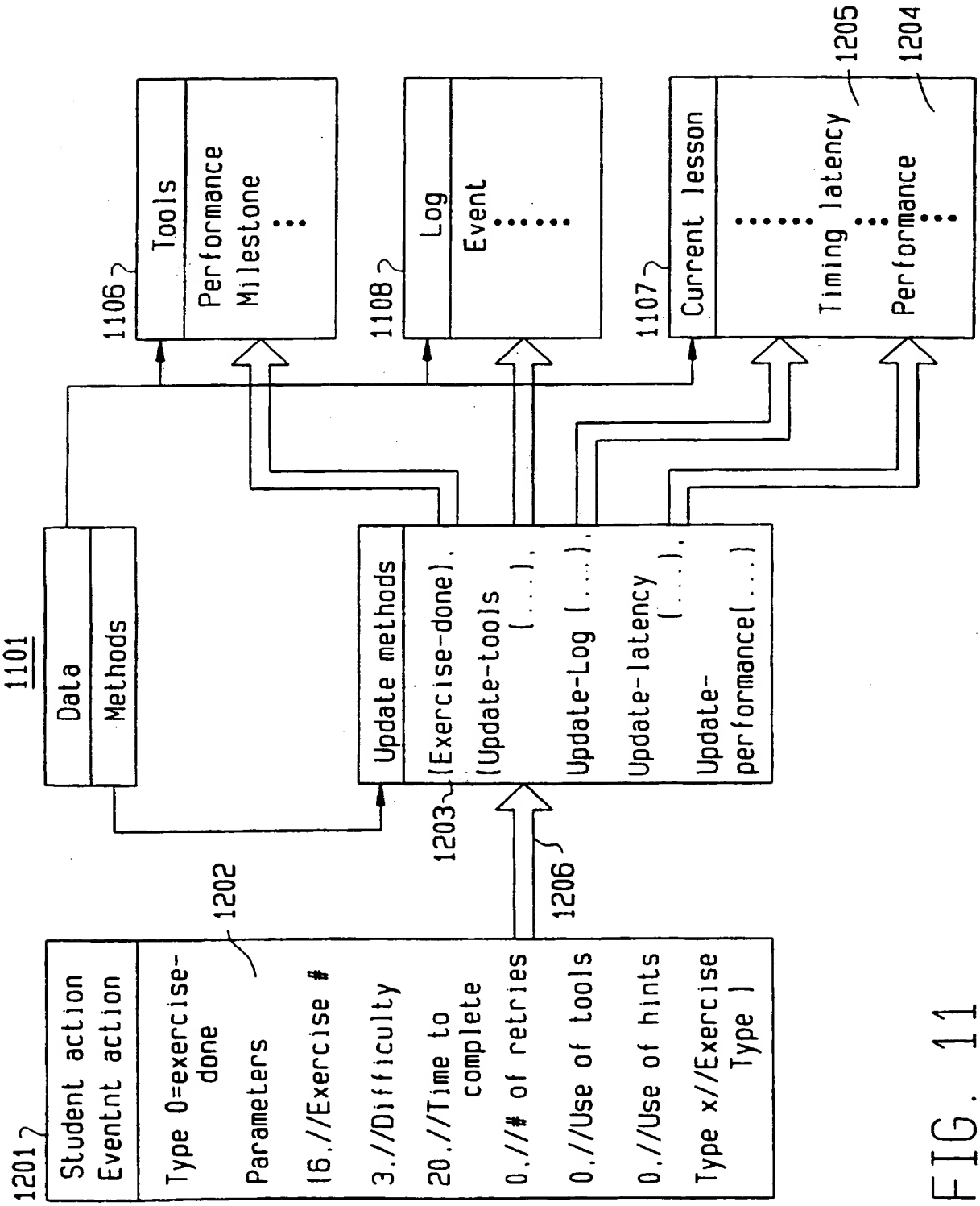
1101
Data
Methods
Update methods
(Exercise-done).
(Update-tools (....),
Update-Log (....),
Update-latency (....),
Update-performance(....)
1203
1206
1201
Student action
Eventnt action
Type 0=exercise-done
Parameters
16.//Exercise #
3.//Difficulty
20.//Time to complete
0.///# of retries
0.//Use of tools
0.//Use of hints
Type x//Exercise Type 1
1202
1106
Tools
Performance
Milestone
1108
Log
Event
1107
Current lesson
Timing latency
Performance
1205
1204

FIG. 11

METAREQUEST METARESPONSE

"Where am I"

"You are one quarter through the lesson on adding fractions."

Student clicks on "More" icon

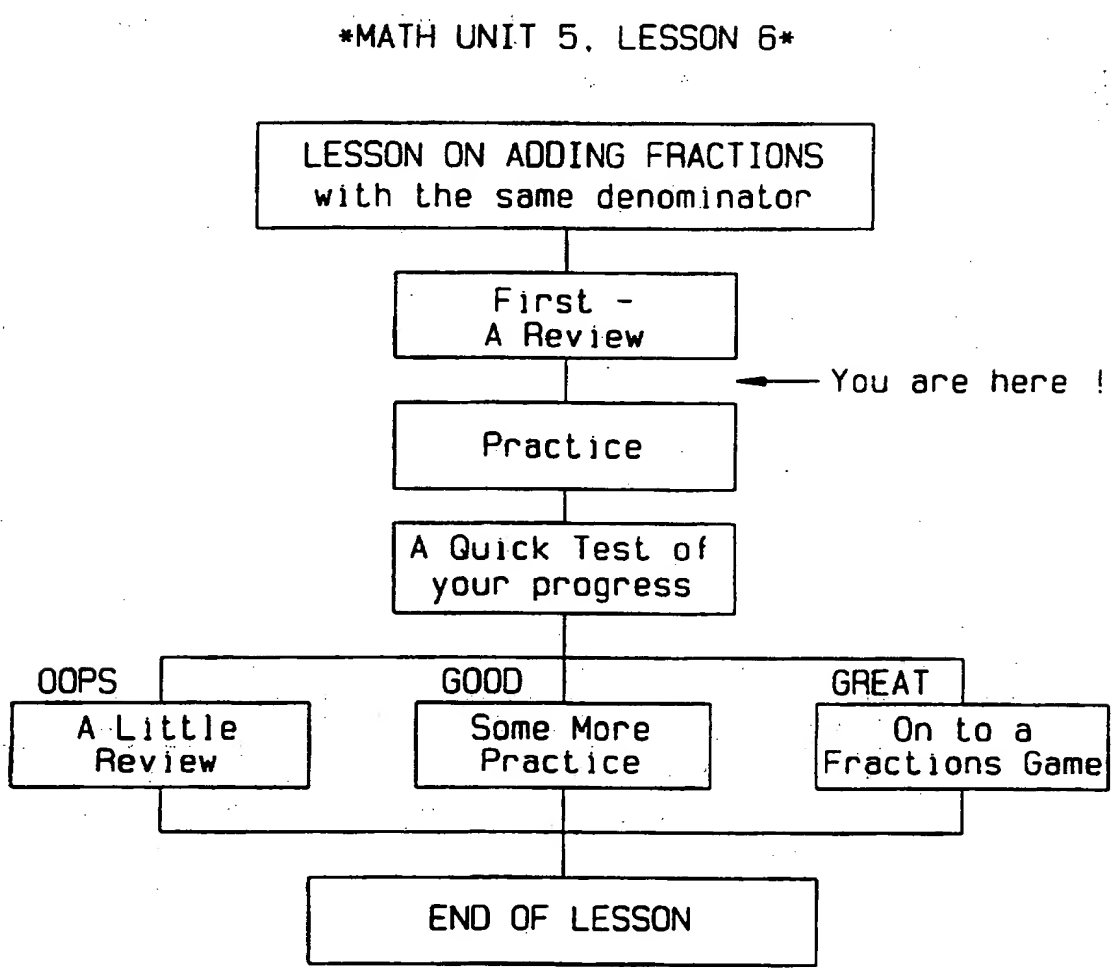

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/08687

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G09B 5/12
US CL :434/350

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 434/350

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- A	US 5,310,349 A (DANIELS et al) 10 May 1994, col. 3, lines 1-40.	1, 11, 12, 23-27, 30-41, 105-109, 111-116, 118,127, 133-135 --- 2-10, 13-22, 28, 29, 40-104, 110, 117, 128-132

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 21 AUGUST 1997	Date of mailing of the international search report 03 SEP 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer WILLIAM H. GRIEB Telephone No. (703) 308-3549

Form PCT/ISA/210 (second sheet)(July 1992)*